(12)

AD_______________

REPORT NO. T14/85

A REVIEW OF PHYSICAL FITNESS AS IT PERTAINS TO THE MILITARY SERVICES

U S ARMY RESEARCH INSTITUTE
OF
ENVIRONMENTAL MEDICINE
Natick, Massachusetts

JULY 1985

UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER T14/85	2. GOVT ACCESSION NO. AD-A166 696	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Review of Physical Fitness as it Pertains to the Military Services		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) James A. Vogel, Ph.D.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Research Institute of Environmental Medicine Natick, MA 01760-5007		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 3E162772A879
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Medical Research and Development Command Ft. Detrick Frederick, MD 21701-5012		12. REPORT DATE July 1985.
		13. NUMBER OF PAGES 51
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

DISTRIBUTION IS UNLIMITED. APPROVED FOR PUBLIC RELEASE (STATEMENT A)

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Physical Fitness, VO_2max, anaerobic power, muscle strength, military

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This review describes the aspects of physical fitness that are pertinent to the military: muscular strength (peak power), strength endurance (anaerobic power capacity), aerobic capacity and body composition. Methodologies for the assessment of each component are described in detail for various applications. An extensive compilation of normitive values from western military forces is presented for each component.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

Citations of commercial organizations and trade names in this report do not constitute an official Department of the Army endorsement or approval of the products or services of these organizations.

Acknowledgment

Sincere appreciation is expressed to members of NATO Research Study Group-4 who critiqued this manuscript, provided data and suggestions for its improvement: Drs. M.F. Haisman, D.J. Smith, C.L. Allen, W.S. Myles, S. Stromme, M.J. Van Dijk, F.M. Bertina, F. Brue, J. Doucet, L. Vanggaard, P. Dubois, H-V Ulmer, A. Reick and J.A. Hodgdon. Appreciation is also expressed to Emily P. Hamilton, Dora A. Ward, Dr. John F. Patton and Major William L. Daniels for their important contributions in the preparation of this report.

Technical Report

No.T14/85

A Review of Physical Fitness as it Pertains to the Military Services

by

James A. Vogel, Ph.D.

Project Reference: 3E162777A879

July 1985

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

NATICK, MA 01760-5007

Foreword

The author of this report served as the United States representative to NATO AC/243 Panel VIII Research Study Group-4 on Physical Fitness during its existence from 1975 to 1985. The activities of the Study Group culminated in the preparation of a comprehensive report of the Group's activities and the subject matter areas that it dealt with. As part of this report, Dr. Vogel was responsible for preparing Chapter 3: "Physiology and Measurement of Physical Fitness". This chapter contained the first known comprehensive review of the scientific study of physical fitness in military forces. It therefore appeared worthwhile to place this review in a form that is more readily available than the NATO report. This Technical Report represents an adapted version of the original chapter prepared for the RSG-4 report.

Table of Contents

List of Tables

List of Figures

Abstract

This review describes the aspects of physical fitness that are pertinent to the military: muscular strength (peak power), strength endurance (anaerobic power capacity), aerobic capacity and body composition. Methodologies for the assessment of each component are described in detail for various applications. An extensive compilation of normitive values from western military forces is presented for each component.

INTRODUCTION

Definition and Components of Fitness

The ability to perform physically demanding tasks is a function of two broad factors: a) the capacity for muscular contraction and b) the neural control of body movement. The latter, which may be referred to as motor fitness, includes the components of neuromuscular control such as coordination, speed, agility and skill. The first factor, commonly referred to as physical fitness, represents the metabolic or energy generating capacity for muscular exercise. In this context, physical fitness can, in turn, logically be subdivided into three separate categories based on the three sources of energy for muscular contraction. These are listed in Figure 1. They are: a) stored energy located in the muscle cell mitochondria in the form of phosphogens, that is adenosine triphosphate (ATP) and creatine phosphate (CP), b) energy in the form of additional ATP and CP that is generated by the anaerobic process of glycolysis, i.e., the breakdown of muscle-stored glycogen into lactic acid and c) energy resulting from the aerobic metabolism of various substrates, referred to as the citric acid cycle and respiratory chain. Because of the kinetics of these three energy sources, each is predominantly associated with a type of exercise described by its intensity and duration. Thus, energy from stored forms is associated with maximal contractions lasting only several seconds. Energy from anaerobic glycolysis occurs in very heavy exercise lasting less than one minute. Aerobically generated energy through the citric acid cycle and respiratory chain is associated with prolonged exercise of a submaximal intensity. In real life tasks or athletic performance, these three fitness

Sources of Energy for Muscular Contraction

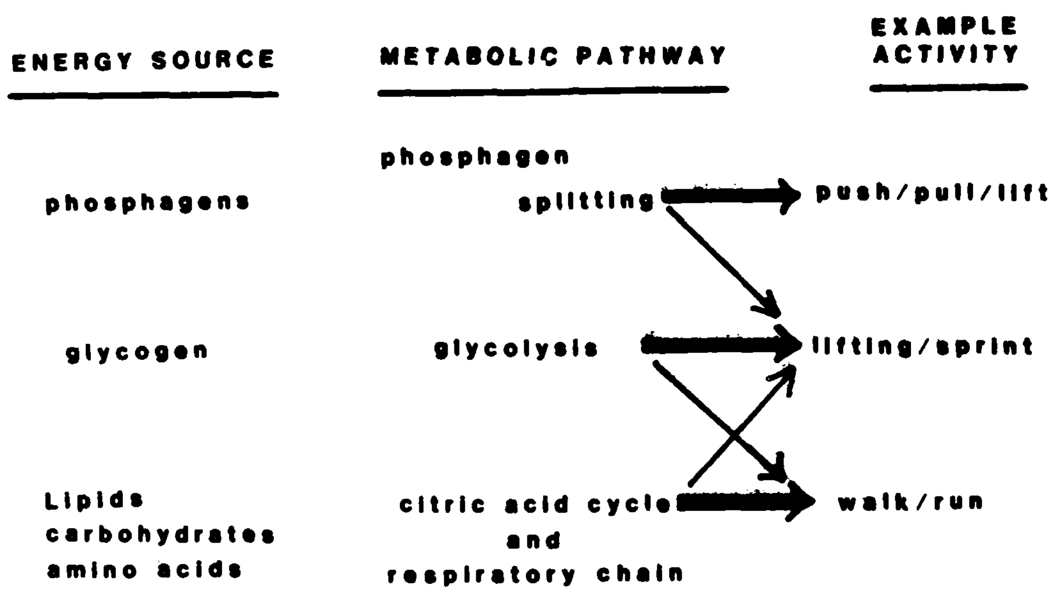


FIGURE 1. SOURCES OF ENERGY FOR MUSCULAR CONTRACTION

or energy generating components overlap, that is, most tasks involve more than one energy source. Nevertheless, they can be separated to a large extent for measurement and training. These three components of fitness or exercise capacity are further outlined and defined in Figure 2. This Figure is not meant to be physiologically perfect but merely to serve as a guide in facilitating this presentation.

Relation of Fitness to Performance

While the capacity to generate energy for muscular contraction may be considered the predominant factor for military physical performance, it must be considered in the total context of factors which influence the serviceman's performance of physically demanding aspects of his job. Figure 3 is an attempt to list other factors which play a role, some of which will be elaborated upon in this report.

PEAK ANAEROBIC (ALACTIC) POWER - STRENGTH

Introduction

As defined in Figure 2, this section will discuss the physiology and measurement of exercise derived primarily from stored phosphogens through a splitting process to release energy for muscular contraction, i.e. muscular strength. It may also be referred to as the alactic component of anaerobic energy generation in order to separate it from anaerobic glycolysis that results in lactate formation. Typical military tasks that consist of a large strength fitness component are lifting, pushing, pulling, throwing and carrying heavy loads for short distances. Despite great advancements in the mechanization and automation of modern warfare, these tasks remain prominently in many military trades. An analysis of occupations in the US Army revealed, for example, that muscle strength is a primary factor in the physical demands of one-third of all enlisted occupations. Currently 76 out

CATEGORIES OF PHYSICAL FITNESS

PATHWAY	ANAEROBIC		AEROBIC
ENERGY SOURCE/ PATHWAY	PHOSPHOGENS/ PHOS. SPLITTING (ALACTIC)	GLYCOGEN/ GLYCOLYSIS (LACTIC)	LIPIDS/GLYCOGEN CITRIC ACID CYCLE
PRIMARY DETERMINANT	MUSCLE MASS	MUSCLE FIBER MAKE-UP	OXYGEN TRANSPORT
DESCRIPTION	VERY HIGH INTENSITY 1-5 SECONDS	HIGH INTENSITY 5-60 SECONDS	MODERATE-LOW INTENSITY 1 MINUTE
EXAMPLE OF ACTIVITIES	LIFT PUSH PULL	LIFTING SPRINTING CLIMBING	RUNNING LOAD BEARING WALKING
PHYSIOLOGICAL TERMINOLOGY	MAXIMAL FORCE/TORQUE PEAK ANAEROBIC POWER (ALACTIC)	ANAEROBIC POWER CAPACITY (LACTIC)	AEROBIC CAPACITY
COMMON TERMINOLOGY	MUSCLE STRENGTH	MUSCULAR ENDURANCE	STAMINA CARDIOPULMONARY FITNESS

FIGURE 2. CATEGORIES OF PHYSICAL FITNESS

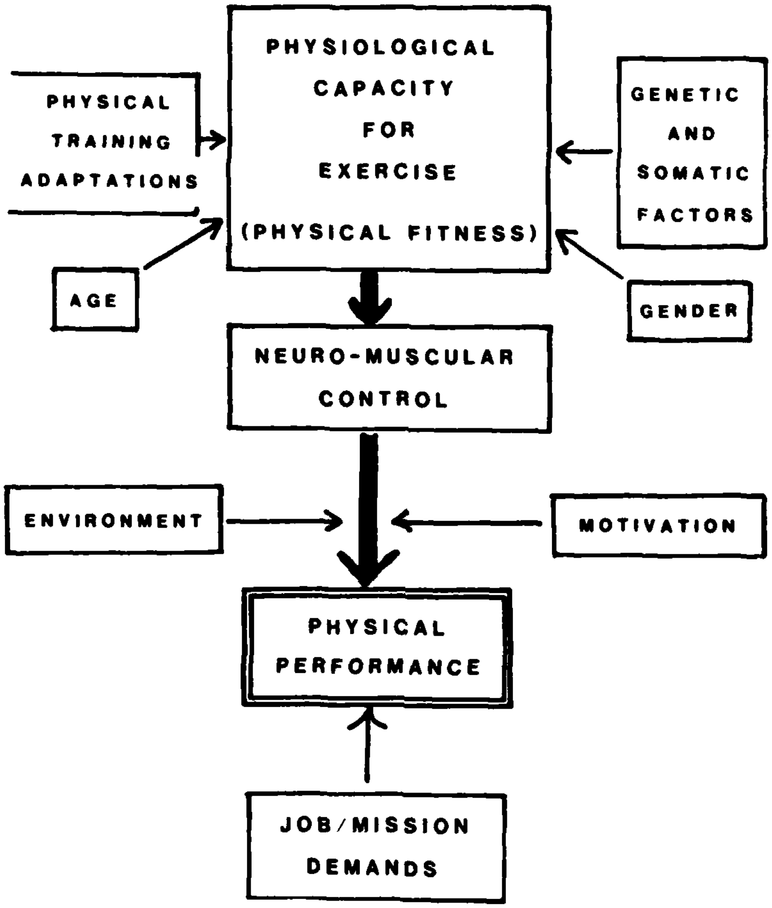


FIGURE 3. FACTORS INFLUENCING PHYSICAL PERFORMANCE

of a total of 350 occupations in the US Army possess a "very heavy" lifting requirement, that is, the ability to lift in excess of 45 kg. Many questions remain concerning muscular strength. For example, what are the upper limits of strength capacity in reference to the repetitive lifting capacity of howitzer crew members; and how can lifting capacity be improved (trained) if weight resistance equipment is unavailable?

Determinants of Strength

Factors which determine the strength of an individual or a group of muscles fall into three categories: a) morphologic, b) neurologic and c) metabolic.

Morphologic factors

The single most important factor related to strength is probably the total mass of muscle involved in a muscle contraction. Muscle mass or size can be represented by its cross-sectional area. Human skeletal muscle produces approximately 6-10 kg of force per square centimeter of muscle cross sectional area in both men and women. However, the absolute force generated will vary depending on the arrangement of the bony levers and their muscular attachments. Thus dimensional or biomechanical considerations come into play along with muscle size itself. This relation between mass and strength is extended to the whole body as demonstrated by the good relationship between maximum lift capacity and total lean body mass, $r = 0.876$, (97) as shown in Figure 4. This relationship is somewhat exaggerated by combining both genders but nevertheless holds up well for the male population.

Neurologic factors

Neurologic factors in strength or force development refer to the neuromotor control of movement which includes the frequency of motor unit firing, synchrony of firing, number of units recruited to fire and the inhibition of the antagonist muscles. The production of maximal force

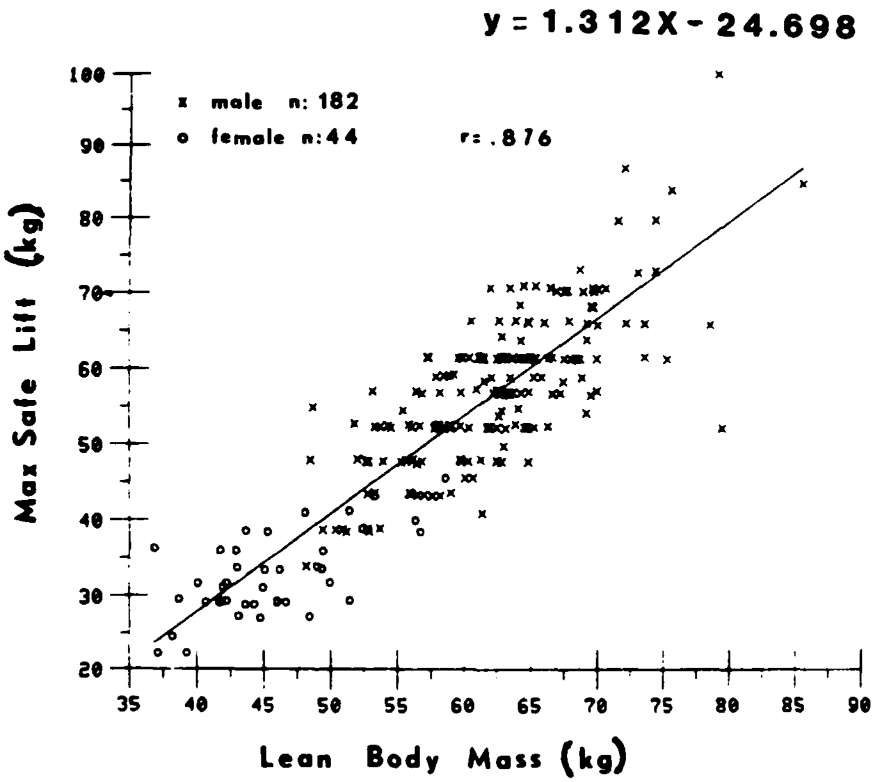


FIGURE 4. RELATION BETWEEN MAXIMUM LIFTING CAPACITY AND LEAN BODY MASS (REF. 98)

(strength) then is not only the total number of muscle fibers involved (muscle mass) but how their involvement is timed and coordinated and the dimensions of the levers over which they are contracted. Optimal neuromotor control is acquired through practice.

Metabolic factors

The metabolic aspect of strength refers to the chemical makeup and physiological nature of muscle fibers. Human muscle contains mainly three types of fibers: a) type I, slow twitch oxidative, b) type IIA, fast twitch-oxidative glycolytic and c) type IIB, fast twitch-glycolytic. Thus these three distinct fiber types are distinguished on the basis of differences in speed of contraction, their fatigue characteristics and their chemical makeup. Relatively speaking, type I fibers are characterized by slow speed of contraction, resistance to fatigue, a higher lipid and lower glycogen and phosphogen content, higher oxidative enzyme content and lower glycolytic enzyme content. Type IIB fibers exhibit essentially the reverse characteristics: fast contraction speed, fast onset of fatigue and contain predominantly substrates and enzymes for anaerobic glycolysis. Type IIA or fast-oxidative-glycolytic fibers may be considered intermediate in nature, having a fast contraction speed but also containing a high oxidative enzyme makeup of their mitochondria. It should be noted that, in general, the two main fiber types, I and II, are a function of their innervation and are genetically determined, not changing over one's life span. The average percentage of type I and II are 52 and 48%, respectively.

Strength type activities (lift, pull, push) are characterized by brief, high intensity contractions and thus would primarily involve Type II fibers. Concomitantly, individuals with a high proportion of Type II fast twitch fibers would be expected to develop higher levels of force and this is supported by the finding that elite strength event athletes have somewhat higher fast twitch fiber contents than the average (77). Fiber typing can to a certain extent be used to estimate ones potential for a particular type of physical activity.

Measurements of Strength

Introduction

A variety of methods are available to quantify muscular strength or the maximal force/tension that is generated by a muscle or muscle group. The choice is based on such factors as safety, availability of equipment and the nature of activity for which the force is employed. This discussion will include: a) field methods which employ only the body's weight and gravity and b) laboratory or in-door methods involving equipment which records force during static or dynamic contractions.

Field measurement

Strictly speaking, our armed forces do not typically apply any pure measures of muscular strength during evaluation in the field. Tests such as push-ups, sit-ups, pull or chin-ups, etc. are, at best, a combination of strength and anaerobic power fitness. Strength is best quantified as the maximal force that can be generated in a brief maximal effort. None of these tests qualify. Furthermore, these field expedient tests often do not evaluate the muscle groups important in military tasks. For example in the Army, the capacity for the common single lift task has virtually no correlation with push-up or sit-up performance scores (60). These common "strength" tests then are largely a motivator and marker for training that are easy to administer. They should not be construed as a true measurement of strength or a measure predictive of military strength tasks. The only attributes are ease and rapidity of administration, universal popularity and access to a large body of reference data.

Some examples of pure strength tests suitable for field measurement include a) vertical jump, b) standing broad jump and c) medicine ball throw. With some minimal equipment, whole body strength could be measured in terms of the maximum weight (weighted box, bag) that could be lifted to a certain height or the maximum weight that could be pushed or pulled (in a sled).

Laboratory or in-door measurement of strength

Introduction

Laboratory measurements of strength can be divided into two modes: a) static or isometric and b) dynamic. Dynamic, in turn, can be subdivided into constant mass and constant velocity modes. All of these have different attributes and different applications with no one mode being necessarily considered superior. Dynamic procedures would seem appropriate in most cases since many military tasks are dynamic rather than static in nature. Isometric procedures gained their popularity from the aspects of safety, ease of administration, preciseness of quantification and minimal equipment needs.

Isometric

A large variety of isometric measures of muscular strength have been used in military fitness research and more recently in operational testing of new entrants into the service. Hermansen (31-33) has reported the Norwegian's use of three isometric measures of strength in conscript screening: a) knee extensions, b) elbow flexion and extension and c) trunk flexion and extension. Based on their work, the US Army evaluated these measures (78,42) as well as handgrip (74) and a 38 cm upright pull (44). Correlation of these individual tests with task performance is questionable. Sharp, et al (78) did report that handgrip, 38 cm upright pull and upper torso downward pull were good predictors of lifting capacity. The US Navy reported on more task specific isometric tests such as a one arm pull using spring loaded dynamometers (76). Both the US (78) and the Netherlands (10) have used isometric testing in research and screening programs but there has been no agreement on standardization of muscle groups or test protocol (75). Bertina, et al (8) has reported that a test angle of 150 degrees is optimal for the isometric knee extension test. Ulmer, et al (87) reported optimal conditions for isometric elbow flexion strength. The best current example of the utilization of isometric strength tests is with the Netherland's "Assessment of Physical Trainability" entry test which includes isometric measurements of elbow and trunk flexion and extension and knee extension (10). It appears safe to conclude that isometric testing of major muscle groups is useful in evaluating new recruits/conscripts for overall generalized strength.

Dynamic

The dynamic measurement of muscular strength refers to the movement of a mass or exertion against resistance through a range of motion. This encompasses the long used "one repetition maximum", referring to the maximum weight that can be lifted once, usually in the form of free weights such as bar-bells. In addition to free weights, many types of machines are now available where movable weights are pushed or pulled through the use of cables or bars. While these instruments are becoming common for training, they are not often used for testing. However, one example of the use of a dynamic one repetition maximum lift test is the current "incremental dynamic lift" (57) now used by the US Army and Air Force for entrance occupational screening. They found this to be superior to isometric tests in terms of predicting lifting capacity (60). The Margaria stair climb test (54) also falls into this category of a dynamic peak power test.

Isokinetic

The most recent development in dynamic muscular strength testing is the use of the isokinetic principle - the measurement of maximal force exertion through a full range of motion while velocity of the contraction is held constant (83). The Lumex Corp. Cybex II dynamometer, originally designed for rehabilitation, is commonly used for isokinetic measurement in research settings (74). Currently appearing on the market are computer-assisted dynamometers that use microprocessors to measure and control force, acceleration and velocity at various speeds and movement patterns.

Peak Power

In the broad category of muscular strength or peak anaerobic power, we should also include tests employing dynamic repetitive contractions, such as can be performed by a cycle ergometer. Thus the peak power output generated during the first 5 seconds of maximal cycling in the Wingate test (7,24) is a measure of muscular strength in that it is a quantification of the available stored phosphogens (alactic). The Wingate test, which also includes a muscular endurance (lactic) component, is described in the section on measurement of anaerobic power capacity. The peak power output at 5 seconds correlates well with muscle strength as measured by the isokinetic peak torque measure (59).

A superior repetitive contraction test of peak anaerobic power is the Brue alactic power test (Wmax An) (12,72). This procedure determines the peak power output obtainable during a series of very brief (3-5 secs) exercise bouts with progressive load (resistance) settings to maximal achievable velocity. Four loads are normally used (8,10,12 and 14 kiloponds) with the subject pedalling to peak velocity at each load. A three minute rest is given between exercise bouts. Load and velocity are plotted to obtain the peak attainable power output (Wmax An). This value is consistently higher than the 5 sec peak value obtained in the Wingate procedure. The cycle ergometer (Ergomeca 600) designed for the Wmax An test, but also suitable for Wingate and aerobic testing, is shown in Figure 5. It is used for exercise testing in the French Forces.

Summary

In the in-door or laboratory testing environment, a wide-range of testing modes are now available. The method of choice will often be based on the time available for testing and the equipment resources available. Within these limitations, strong consideration should be given to procedures that closely mimic or predict the tasks for which the measurements are being made. Thus, dynamic testing modes will no doubt become more popular in the future and replace the often used static measures.

Values of Strength in Military Populations

General

Because of the numerous methods and variations within methods of evaluating muscular strength, a comprehensive picture or profile of strength in military forces is almost impossible to obtain. Little attention has been given to describe levels of muscular strength as they exist in the military and factors which influence them. The following discussion is limited by these constraints. It will not include "field tests" such as push-ups and sit-ups because of the variation in their administration.

Gender

Table 1 presents a compilation of isometric strength data that is available from male military populations. Table 2 adds isokinetic strength values of the arm and leg in three samples of infantry soldiers. Table 3 contrasts male and female strength data available from military samples. The

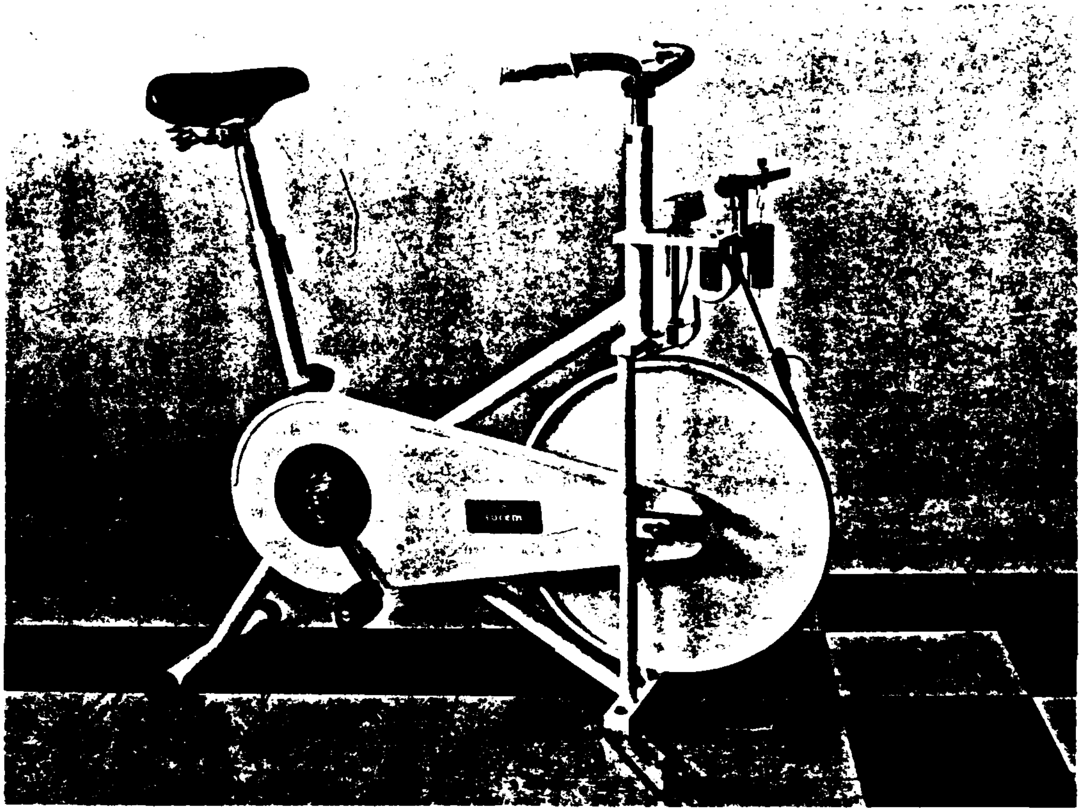


FIGURE 5. THE ERGOMECA 600 CYCLE ERGOMETER

TABLE 1. Maximal Isometric force values (kp) from male military populations

Reference	Subjects	Handgrip	Elbow flexion	Knee extension	Trunk flexion	Trunk extension	38 cm UP	Horiz. arm pull
63	Swedish Marines n = 257	69.1	58.8		69.1	87.5		
31	Norwegian Military conscripts n = 1237		27	134	69	89		
2	British Army recruits n = 3065	38.4						
56	US Army recruits n = 102						103.9	
45	US Army recruits n = 769			158.2		79.0		
60	US Army recruits n = 462	52.6					148.8	
98	US Infantry n = 50			161		77		
76	US Navy recruits n = 350	46.1						71.1
43	US Infantry n = 32	56.2		186.0		89.4	130.6	
52	US Navy trainees n = 69	52.2						70.0
78	US Infantry n = 221	54.0		167.6		80.0	138.0	
64	Canadian Forces n = 56	53.0		196.7		88.4	144.0	
84	British Parachutists n = 22	39.1	25.8	151.5	70.1	94.4		
16a	Dutch recruits n = 3642		25.6		80.5	96.5		

TABLE 2 Isokinetic muscle strength values in male military populations. Values are expressed in Newton - meters of peak torque

Reference	Subjects	Elbow flexion 30°/sec	Elbow flexion 180°/sec	Knee extension 30°/sec	Knee extension 180°/sec
98	US Infantry n = 50	56.5	40.5	215.0	178.0
43	US Infantry n = 32	53.6	41.1	222.5	128.6

Table 3 Male-female comparisons of muscle strength in military populations

Reference	Isometric Handgrip (kp)			Isometric Knee extension (kp)			Isometric Trunk Extension (kp)			Isometric 38 cm upright pu'l (kp)			Isokinetic trunk extension at 36°/sec peak torque, Nm		
	M	F	F/M	M	F	F/M	M	F	F/M	M	F	F/M	M	F	F/M
63	52.6	33.7	.64												
76	46.1	28.5	.62												
78	54.0	34.1	.63	167.6	99.3	.59	80.0	51.3	.64	138.0	83.7	.60	286.9	163.2	.57
45				158.2	106.6	.67	79.0	56.6	.72						
60										148.8	95.2	.63			
56										103.9	58.3	.56			
16a							96.5	70.9	.73						

data in this latter table suggests a rather consistent female-to-male ratio of between 0.60 and 0.70. This agrees rather well with Laubach's review (50) of the gender comparison in strength where he found that the ratio averaged 0.56 for upper extremities,0.72 for lower extremities and 0.64 for trunk strength. Pheasant (71) also found a F/M ratio mean of 0.61 for a variety of isometric tests, the ratio being higher in the lower extremities. This difference in strength can be attributed largely to differences in muscle mass. If strength is corrected by body size or lean body mass this gender difference largely disappears. The finding of a larger ratio in the lower body is explained by a relative lack of muscle mass and use of the muscles of the upper body in females as compared to the legs. The F/M ratio for actual lifting capacity is less than it is for strength (Table 4). This can be explained by differences in biomechanics between the genders.

Age

No data are available from military populations concerning changes with age. Larsson, et al (49) showed in 114 male civilians that both isometric and dynamic strength increased up to the third decade, remained constant to the fifth decade and thereafter decreased with increasing age.

Peak power values

Values of muscular strength or peak alactic power as measured by repetitive contractions (cycle ergometer) are shown in Table 5.

Strength Training

General

Strength can be increased through a process of progressive resistance training. Thus, as the muscle becomes stronger, greater weight or resistance must be applied in the training process to yield continued improvements. Furthermore, it is well known that a very high intensity (90-

Table 4 Male-female comparisons of one-repetition maximum lift capacity in military populations. Values are in kilograms

Reference	Max lift to 132 cm			Max lift to 152 cm			Max lift to 183 cm			Max lift to shoulder height			Max lift to elbow height		
	M	F	F/M	M	F	F/M	M	F	F/M	M	F	F/M	M	F	F/M
96	77.7	35.5	.46												
78	57.6	32.5	.56												
60				65.5	34.4	.53	62.1	30.4	.49	50.8	30.2	.59			
57							51.8	25.8	.50				58.6	30.7	.52

Table 5: Values of peak anaerobic (alactic) power

in military personnel (ref. 59, 66 and 12)

Reference		Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Single load test		Upper Body			Lower Body			Whole Body		
59	Peak Power (Watts)	587	112	426-875	632	125	393-945			
66	Peak Power (Watts)	521	63	393-605	783	85	606-961			
12	Peak Power (Watts) Resistance-setting: .075 kp/kg BW							745	120	598-1036
Miltiple load test										
12	Peak Power (Watts)							1026	193	736-1498

100%) of effort, rather than a prolonged low to moderate intensity is most effective in strength development. Training with resistances of 80-90% of maximum is most effective in enhancing muscle hypertrophy, a primary factor in strength development. A comprehensive review of strength training has been prepared by Atha (5).

Isometric

Isometric training is not commonly used in the military and is generally losing popularity. The gains in strength with isometric training appear to decrease with time more so than with dynamic training and are maximal only at the joint angle maintained during training.

Dynamic

Dynamic training of an isotonic mode, such as with free weights or machine weights (such as a "Universal Gym"), is most common. General guidelines would include: a) moderate to high resistance (70-90% of one rep max), b) 5-6 repetitions per set, 3-4 sets, and c) short rest periods between sets (work: rest ratios from 1:2 to 2:1).

Isokinetic

Isokinetic training refers to exercise where the velocity is maintained constant throughout the range of motion through the use of mechanical or computer controlled devices. Despite its effectiveness, its use is limited because of the relatively high cost and large number of machines required - separate machines being designed specifically for each muscle group.

Military

Strength training in our military forces does not always receive the attention given to aerobic training although there are exceptions to this. This is in part due to the: a) lack of appreciation of strength requirements for military performance, b) lack of strength training equipment, c) lack of time for individualized methods or attention, d) ease of mass administration of simple, but non-effective, exercises, and e) lack of an understanding of the basic principles of strength training. Large group exercises (calisthenics) and drills (log, rifle) are still commonly used but are likely to be relatively ineffective in enhancing muscular strength. In the military setting most strength is probably gained from repetitively doing one's job. This however does not produce a "strength reserve" for the emergency situation of war-time. This lack of emphasis on strength training is further illustrated by a lack of research reports on this topic in the military setting.

Circuit training

A relatively recent advancement in strength training is referred to as "circuit weight" training. It is characterized by the trainee proceeding through a series of weight stations consisting of free weights, isotonic and isokinetic machines. By rapidly moving from one station to the next, it is believed that gains can also be elicited in muscular endurance and aerobic capacity as well as strength. It generally consists of relatively low resistance (50-60% of one rep max), 12-20 repetitions and minimal rest periods between sets (10-20 secs). Marcinik, et al (52,53) have contrasted such circuit weight training schemes in Navy men and women with aerobic-calisthenic type programs. In men, the circuit program produced significantly greater dynamic muscular strength and strength endurance changes than a standard calisthenic program. Similar findings were found in women.

Summary

It is evident that mass calisthenic exercises of the type often used in the military are ineffectual in enhancing muscular strength. The use of individualized progressive weight resistance is necessary for time efficient strength training. Weight machines (movement of weight through the aid of cables, levers or cams) are not required but external weight in the form of bar bells, weighted boxes or objects or resistance provided by another person is necessary.

ANAEROBIC POWER

Introduction

This section will discuss the physiology and measurement of anaerobic power as defined in the Introduction to this report. The term anaerobic power capacity will be used synonymously with muscular endurance and refers to that aspect of exercise capacity characterized by brief (5 to 60 sec) high intensity effort which derives its energy primarily from anaerobic glycolysis. In contrast to strength and aerobic capacity this component is a much less well characterized area of exercise capacity due to the inherent difficulties in its study. For the same reason, much less has been done in the area of measurement, population values and response to training, especially in military personnel.

Determinants of Anaerobic Power

Muscle fiber

The ability to sustain a high intensity constant (isometric) or repetitive (dynamic) muscular task for periods of 5 to 60 seconds will depend on a) the mass and nature (fiber type) of muscles involved and b) the capacity of anaerobic pathways for glycolysis within these muscle fibers. As discussed earlier, a high ratio of Type II fast twitch fibers will favor a high anaerobic power. The relationship between a high percentage of fast twitch fibers and anaerobic power production has been reported by Bar-Or, et al (6) and Bosco, et al (11).

Metabolic profile

Metabolically, anaerobic power is related to the ability to convert glycogen to lactic and pyruvic acid and, at the same time, tolerate the increased acidity due to their accumulation. Thus, as one improves anaerobic power through training, the following changes take place: a) increases in glycolytic enzyme content of the muscle (e.g. lactic dehydrogenase, hexokinase, phosphofructokinase), b) increased levels of substrates - glycogen and phosphogens, and c) enhanced tolerance for lactic acid levels in the muscle fiber and greater ability to convert lactic acid. Gollnick and Hermansen (27) have reviewed this topic.

Measurement of Anaerobic Power Capacity

Introduction

As compared to strength and aerobic capacity, our ability to quantify anaerobic power is much less precise and, until recently, has been largely ignored in the laboratory. This stems from the fact that it is impossible to isolate out this component as is possible with the other two fitness components. Earlier efforts to use oxygen debt and lactic acid accumulation for quantification of anaerobic power have not been satisfactory. Thus, we are left with "performance" measures - measures of the maximum power output that can be generated in a specific time and activity that coincide predominantly with energy derived from glycolysis. Therefore, the criterion for developing such a test would be very high intensity for periods lasting 10-60 secs.

Field measurement

A sprint run test qualifies as an anaerobic power test. A 40-60 second maximum sprint or a 100-200 meter sprint would be typical tests that could be used in the field. Shuttle runs and man-carries are other whole body events of anaerobic power capacity. Push-ups, chin-ups and sit-ups are also tests of muscular endurance of specific muscle groups.

Laboratory or in-door measurement

Isokinetic fatigue test

Several anaerobic power capacity tests have recently been developed using laboratory ergometers or dynamometers. These give better precision and reliability than can often be achieved in the field measurements just mentioned. The first of these is referred to as the isokinetic fatigue test as developed by Thorstensson (83). It uses 50 repeated maximal isokinetic contractions performed in 60 seconds at an angular velocity of 180° per second. The average torque and rate of torque decline are utilized as quantifiable parameters.

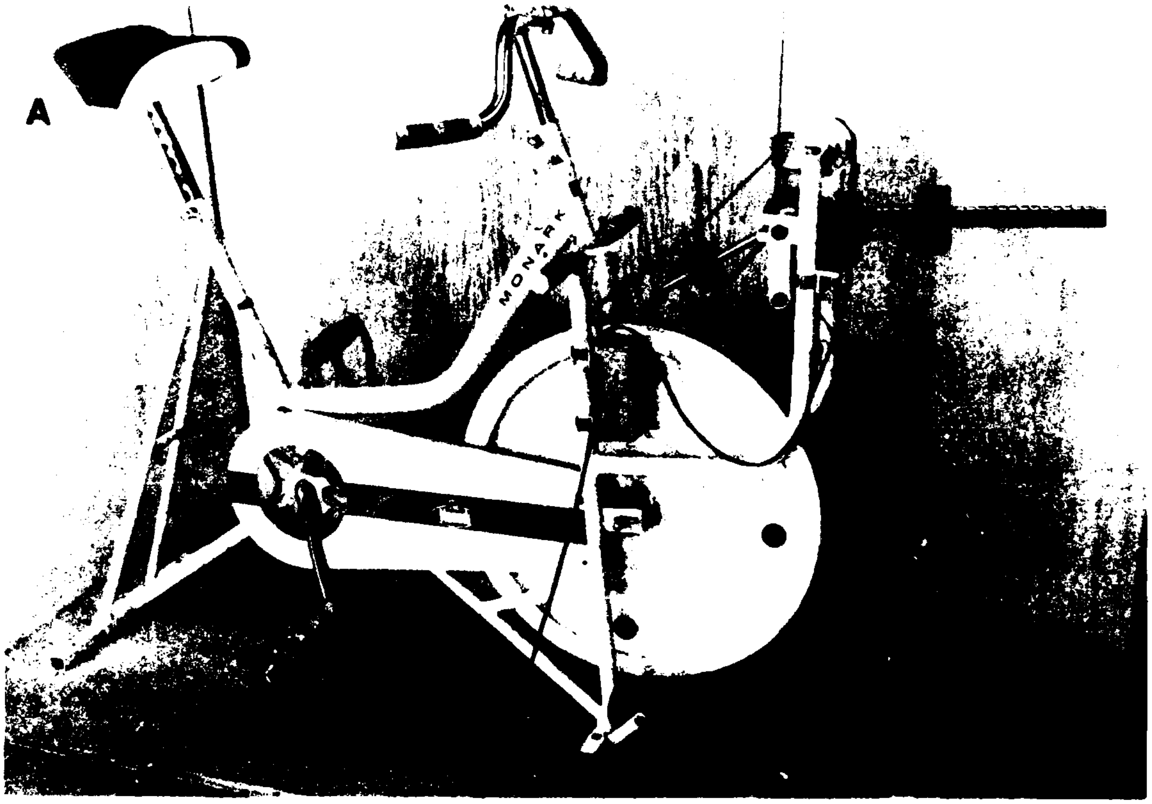
Wingate test

A second test (Wingate test) uses a cycle ergometer (7,24). The ergometer, after abrupt application of the resistance, is pedalled or cranked at maximal possible revolutions for thirty seconds. Power output is calculated for the mean of 30 seconds as well as the rate of decrease. This procedure can be used for both leg pedalling and arm cranking. It has a good correlation with the Thorstensson fatigue test (59). The Wingate test is illustrated in Figure 6. It should be pointed out that the Wingate anaerobic test, that is the mean power output over 30 seconds, also includes the phosphogen alactic component and therefore is not a pure glycolytic or lactic component test.

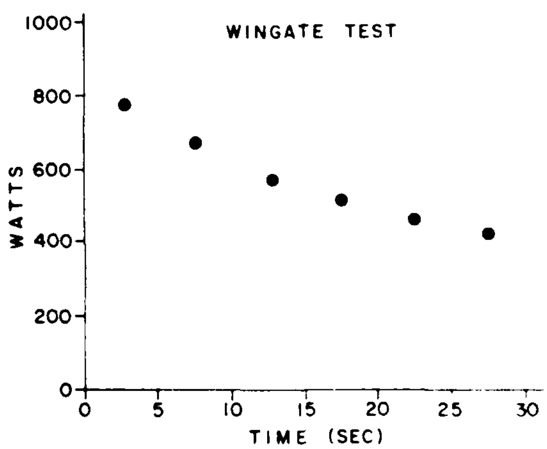
Isometric endurance time

A commonly employed test of muscular endurnace that may fall into the category of anaerobic power is a measure of isometric endurance time. The procedure typically records the time that an individual can maintain some percentage of maximal isometric force, usually between 50 and 75% (13a, 87).

A



B



C

SUBJECT NUMBER . . . 8216

TIME (SEC)	CUM REV.	REV. 5 SEC	WATTS
5	12.8	12.8	775.1
10	23.8	11.0	669.0
15	33.4	9.6	579.3
20	41.9	8.5	518.1
25	49.6	7.7	465.0
30	56.5	6.9	420.2

RESISTANCE	.073
FORCE (KG)	5.2
AVG POWER	571.4
PEAK POWER	775.1
POWER DEC	14.2
HEART RATE	196

FIGURE 6. WINGATE ANAEROBIC TEST A: Modified Monark cycle ergometer, B: Plot of power output, C: Computations of endpoints

Whether this measure is a true reflection of anaerobic power potential of the involved muscles or whether it is complicated by the restricted blood flow to the muscles that occurs with static contractions can be questioned. The circulatory responses to these type of measures are well know (5a, 70a).

Values of Anaerobic Power Capacity in Military Populations.

Two reports have been found, that by Murphy, et al (59) in 34 infantry soldiers and by Patton and Duggan (66) in 15 British soldiers. Values from these studies for the Wingate upper and lower body and the Thorstensson isokinetic fatigue test for the arm and leg are given in Table 6.

Anaerobic Power Training

Fitness training for improving anaerobic power is typically carried out in the form of high intensity interval training. This mode of training is a series of repeated bouts of exercise alternated with periods of relief. In this case, the periods of exercise are of a very high intensity so that the anaerobic metabolic pathways are engaged. The rests or relief periods enable one to repeatedly load the anaerobic system without achieving complete exhaustion. Such a training scheme builds a tolerance to accumulated lactic acid. For example, one would sprint near maximum for one minute followed by 3 minutes of recovery. Several repetitions of this cycle causes lactate to "stack up" and force the muscles to accommodate to these high lactate concentrations. Research on anaerobic power training in the military setting has not been reported.

AEROBIC POWER

Introduction

The last to be discussed but the best understood component of

TABLE 6 Values of anaerobic power capacity in Military Personnel (Ref. 59 and 66).

Reference		Mean	SD	Range	Mean	SD	Range
	Wingate Test	Upper Body			Lower Body		
59	Mean Power (Watts)	424	73	301 - 567	440	101	238 - 683
66	Mean Power (Watts)	383	42	312 - 481	611	57	520 - 699
	Isokinetic Test	Elbow Flexors			Knee Extensors		
59	Mean Peak Torque (Nm)	23	7	12 - 52	78	17	52 - 121
66	Mean Peak Torque (Nm)	19	3	14 - 25	77	13	58 - 105

physical fitness is that of aerobic power. Despite mechanization and the fact that our military forces often ride or fly to their destination, the vast majority of daily military tasks probably fall into this category. This component of fitness is most often studied because it can readily be isolated from the other components. Its emphasis in the military is due not only to its relationship to many military tasks but also to its use for health maintenance, body weight control, building of unit esprit and the fact that it is simple to administer and requires no equipment. The benefit of aerobic fitness and the gains achieved by increasing aerobic capacity through physical training must be emphasized in our military forces today.

Determinants of aerobic power

Introduction

The capacity to generate energy through the aerobic (citric acid) metabolic pathway is a function of the various components of the oxygen transport system. This begins with pulmonary ventilation and ends with oxidation of substrates in the mitochondria. The rate limiting component along this chain may vary depending upon the existing conditions but usually is thought to be the heart's pumping capacity, cardiac output. This topic is reviewed by Kaijser (39).

Central factors

To begin the aerobic process, oxygen must be brought into the lung's alveoli and the gas diffused to the hemoglobin of the circulating erythrocytes. Neither of these steps appear to be limiting factors in healthy individuals. There is no evidence that minute ventilation reaches a plateau, in fact, it continues to increase exponentially with increasing exercise intensity. Near complete oxygen saturation of the arterial blood, even at maximum exercise, suggests that this step is also not limiting to aerobic capacity in healthy individuals.

The next step in the aerobic transport process is the pumping action of the heart to deliver blood to the exercising muscles. This action, or cardiac ouput (total blood flow per minute), is a product of the heart beat frequency (heart rate) and the stroke volume of each heart contraction. It has been shown that cardiac output does reach a limit that coincides with maximal exertion and maximal oxygen delivery. Heart rate and cardiac output show a tendency to level off as maximal oxygen transport (maximal oxygen uptake) is achieved. The maximal cardiac output that can be achieved is essentially a function of the size of the stroke volume of that individual.

Peripheral factors

Local blood flow to the exercising muscles is a function of cardiac output, vasomotor control of peripheral resistance and the anatomical size of the vascular bed. Mounting evidence suggests that muscles are capable of much higher flow rates than they normally receive, again suggesting that cardiac output is the primary determinant of oxygen transport and therefore of aerobic capacity. An exception to this may be when a limited muscle mass is involved in which case oxygen extraction is limiting rather than cardiac output.

An alternative to cardiac output being the primary determinant is the oxidative capacity of the muscle cells to utilize the delivered oxygen for substrate oxidation to replenish phosphogens. Thus, the number and size of mitochondria and their concentration of the enzymes of the respiratory chain could be the rate limiting factor of aerobic capacity. Even though this controversy continues, the majority of evidence supports the contention that in the healthy exercising human, blood flow delivery to the muscles (cardiac output) is the main determinant of one's aerobic fitness level.

Measurement of Aerobic Power and Performance

Introduction

The development and validation of methods for both the actual and predictive measurement of aerobic capacity have been very extensive. Yet because of the key role of aerobic fitness in both job performance and health promotion, extensive activity continues in the refinement and description of techniques for this purpose. While actual measurement (collection and analyses of expired gases) of maximal oxygen uptake during progressive treadmill or cycle ergometer exercise is considered the "gold standard" measurement of aerobic capacity, there are many occasions where this technique cannot be applied and a predictive procedure is called for. Both will be discussed in this section.

Measurement of Aerobic Power

The internationally accepted procedure for determining aerobic power is the measurement of maximal oxygen uptake. This is defined as the point (in a progressive exercise test) in which oxygen uptake no longer increases despite an increase in exercise intensity (82,58). Most laboratories use a criterion of not more than 1.5-2.0 $ml \cdot kg^{-1} \cdot min^{-1}$ per incremental increase in exercise intensity (such as a 2 percent treadmill grade increase). The choice of the treadmill or cycle ergometer is based on tradition and availability of equipment. The treadmill does produce higher maximal O_2 uptake values (34), avoids the possibility of local muscle fatigue becoming limiting as can be the case with cycle ergometer exercise and, of course, is a mode of exercise more common to military activities than is cycling. Cycles offer the advantage of providing precise information concerning the load being applied but this is not necessary information for the actual determination of maximal O_2 uptake. Another variation in procedure is whether the sequential loads are applied separately with intervening rest periods or applied in a continuous step or ramp scheme (81). The separate or interrupted procedure is recommended if time is available as it yields slightly higher values, more comfortable for the subject and therefore easier to gain subject cooperation, and minimizes complication from other factors such as local muscle fatigue.

Estimation of Aerobic Power

Introduction

The majority of current methods used to estimate or predict maximal oxygen uptake (without actual measurement of oxygen uptake) are based on the heart rate response to submaximal exercise (55). It is well established that heart rate increases in a nearly linear fashion with increasing exercise intensity until the individual's maximum rate is reached. Since maximum rate is closely related to age, and the oxygen uptake - exercise intensity relationship is quite consistent, then the determination of submaximal heart rate can be used to estimate, by extrapolation, the oxygen uptake that would occur at maximal heart rate. This procedure is depicted in Figure 7. The position and slope of the HR:$\dot{V}O_2$ plot is a function of aerobic capacity, shifting to the right with increasing capacity. Accepting this, a common and even simpler alternative is the determination of W_{170} or the exercise load that is achieved at a heart rate of 170 (94,88). In this procedure, one determines the position of the line (and therefore the level of aerobic capacity) by a measurement at one point on the line. There are many variations of these two common procedures (1,3,4,21,23,29,79,80) too numerous to elaborate on here. Both can be applied to either cycle ergometry or graded stepping exercise. While a stepping test requires less expense, a cycle test to predict maximal O_2 uptake is recommended due to the greater

PREDICTION OF MAXIMAL O_2 UPTAKE

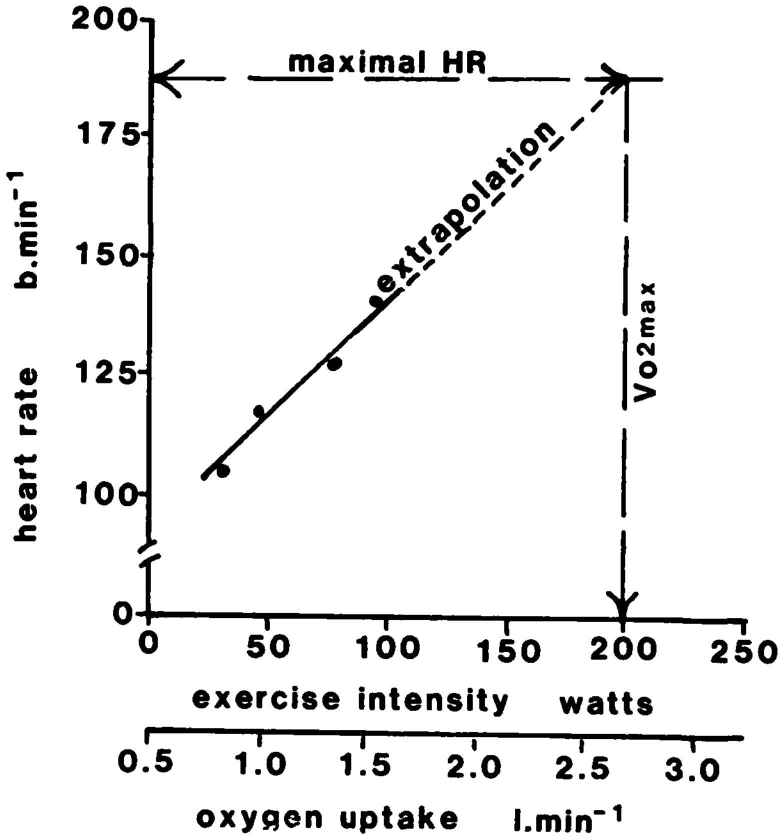


FIGURE 7. SCHEMATIC OF PROCEDURE FOR PREDICTION OF VO2max BY THE SUBMAXIMAL HEART RATE EXTRAPOLATION TECHNIQUE

ability to establish and control the exercise intensity. Nevertheless, a step test, developed in the UK in which the heart rate measured during submaximal exercise is used in regression equations incorporating lean body mass or percent fat has been shown to five a good correlation with measured maximal O_2 uptake (18,19) and best time on a 1.5 mile run (80a). Such an approach has been used with success by the Belguim Air Force. Estimation of aerobic capacity from post-exercise (recovery) heart rates is not recommended and generally unnecessary with the wide availability of electronic heart rate detectors.

NATO $\dot{V}O_2max$ prediction test.

The most commonly used procedure for predicting $\dot{V}O_2max$, the Astrand-Ryhming Cycle ergometer procedure (4), has often given disappointing results. With the goal of improving upon this procedure, a NATO Research Study Group on Physical Fitness set about to devise a test which would give closer agreement to measured $\dot{V}O_2max$. A procedure was desired to estimate maximal O_2 uptake that did not require the assumptions of maximal heart rate related to age or was not subject to abnormal variations in the heart rate - exercise intensity relationship. A proposal was developed for a new test which was referred to as "NATO I", based on a rapid increase in load as later reported by Ulmer (88). This procedure employed a cycle ergometer which was pedalled at 75 rpm with the intensity increased 37.5 watts each minute until inability to continue. Thus, it avoided any assumptions concerning heart rate responses and estimated maximal O_2 uptake from the highest exercise load that could be achieved in an incremental load test. Ulmer has suggested (88) that the NATO I test be hereafter referred to as the W_{max} test.

Since its introduction by Ulmer (88), the W_{max} test has been extensively investigated by a number of NATO participants (69,62,27,35,70) and compared to measured maximal O_2 uptake with good results. Table 7 contains correlation coefficients between W_{max} and measured VO_2max and other predictive tests.

The W_{max} test results can be presented in absolute terms as the highest wattage or exercise time achieved, or these scores can be converted into VO_2max values through derived regression equations (17,35,69,62). Such equations are:

Eq. #1 $\dot{V}O_2max = 0.012$ watts $- 0.099$ Ref. 69

$r = 0.89$

Eq. #2 $\dot{V}O_2max = 0.301$ minutes $+ 1.247$ Ref. 62

$r = 0.79$ SEE $= 0.250$

Eq. #3 $\dot{V}O_2max = 0.353$ minutes $+ 0.825$ Ref. 17

$r = 0.61$ SEE $= 0.461$

Eq. #4 $\dot{V}O_2max = 0.414$ minutes $+ 0.775$ Ref. 35

$r = 0.68$ SEE $= 0.367$

$\dot{V}O_2max$ is expressed in liters per min in each case.

Maximal intensity tests are not always possible or suitable and therefore a submaximal version was developed, referred to as NATO II. This procedure employs the same exercise conditions as W_{max} but uses as the end point the exercise intensity achieved at a heart rate of 190 minus age. Additional evaluations and clarifications of these two tests have been reported (85a, 86).

Field Tests

While ergometers are typically used to sample aerobic fitness of selected populations on entrance testing in our military forces, they are seldom used for periodic fitness evaluation of troop populations. Such tests for this purpose have included the one mile, one and one-half mile or two

TABLE 7 Correlation coefficients between the NATO I (W_{max}) test and other measured and predictive tests of VO_2max in male soldiers.

Reference	Measured VO_2max by cycle	Measured VO_2max by TM	Astrand-Ryhming
69	.89	.87	.83
62	-	.79	.70
17	.61	-	-
35	.68	-	-
70	-	.82	.57

mile run for time or the 15 minute for distance tests. The correlation coefficients between these tests and measured $\dot{V}O_2$max generally range from 0.6 to 0.8. Under optimal conditions, they can range as high as 0.9. Thus timed runs, particularly 1.5-2.0 miles, are considered good estimates of aerobic capacity if the individuals are motivated to do well.

Brue (13) has recently reported a new and unique version of a run test for $\dot{V}O_2$max estimation. The procedure involves a series of runs on a tract at progressive velocities (running speeds). The speeds are precisely set by a cyclist which the runners follow. $\dot{V}O_2$ is estimated from the known relationship with speed as in treadmill running and $\dot{V}O_2$max determined from the highest running velocity that the runner can achieve.

Summary

In summary, the optimal measurement of aerobic capacity is by the actual gas analyses determination of maximal oxygen uptake by interrupted load uphill treadmill running. Other tests in priority of desirability would be continuous load treadmill, interrupted load cycle ergometer and continuous load cycle ergometer. If actual gas measurement of oxygen uptake is not possible, then the NATO-I test employing a cycle ergometer is the next method of choice. If a maximal test cannot be utilized, the NATO-II version is recommended.

Aerobic Performance

The discussion thus far has dealt exclusively with the measurement and estimation of aerobic capacity, i.e., maximal O_2 uptake. However, it is well known that performance of aerobic type tasks or events, such as long marches or marathon runs are not solely a function of aerobic capacity but also include other physiological factors that relate to the utilization of energy substrates (38). This latter component is thought to be related to the ability of the exercising muscles to aerobically utilize lipids and carbohydrates and, conversely, its ability to avoid the anaerobic metabolic pathways of glycogen utilization which results in blood lactate accumulation. Thus, the higher the capacity of the body to use aerobic pathways, the higher the capacity will be to perform aerobic tasks or events before they are limited or terminated by excess muscle tissue acidity or depletion of carbohydrates reserves. The latter can be conserved if the body has a greater capacity to aerobically metabolize lipids. In summary, aerobic performance is a function of a) aerobic power ($\dot{V}O_2max$) and b) capacity to aerobically metabolize lipids and carbohydrates. This latter capacity is a function of the chemical makeup of the muscle fibers.

A great deal of research has been carried out to develop a simple physiological test of this muscle metabolic capacity. The results of this research has led to a measure which is commonly referred to as "anaerobic threshold" (40). This is an unfortunate term in that it is really a measure of aerobic metabolic capacity, not anaerobic. Anaerobic threshold is defined as the point of exercise intensity where blood lactate begins to accumulate above resting levels. Thus, the higher the aerobic metabolic capacity of an individual or the higher the individual can exercise without lactate accumulation, the higher the anaerobic threshold value. Untrained individuals have a threshold at a work intensity of about 50% $\dot{V}O_2max$ while highly trained aerobic endurance athletes will have lactate thresholds of about 80% $\dot{V}O_2max$. In other words, individuals who have a high capacity for aerobic performance not only have high maximal O_2 uptakes but they can also exercise at higher exercise intensities (utilizing a greater percentage of lipid substrates) before accumulating blood lactate and muscle acidosis.

A number of procedures have been reported to identify the anaerobic threshold. Optimally, one performs a series of progressively increasing submaximal exercise loads with blood lactate being measured at each step. The work intensity at which lactate deviates from resting levels can be used as the threshold value. Others (51) have used the level of a fixed lactate value, 4 millimoles, as the threshold point. Others (93) have used respiratory parameters which are closely linked to lactate acidosis. Regardless of which procedure is selected, there seems little doubt that aerobic metabolic capacity as indicated by blood lactate accumulation is a strong indicator, independent of $\dot{V}O_2$, of the body's capacity for aerobic activities.

Values of Aerobic Power in Military Populations

Table 8 presents a compilation of available data on measured maximal oxygen uptake in military populations. Several observations can be made from these data. First, comparisons of results using different procedures are difficult at best. It is obvious that the walking Balke test gives lower values than the interrupted running procedure. Comparison studies (26) indicate that walking tests must be corrected upward by 10% to be comparable to running tests. Treadmill gives approximately 7% higher values than the cycle ergometer. Interrupted loads are 1-2% higher than continuous loading. Secondly, aerobic capacity declines with age, even to some degree in well trained individuals. This is illustrated in Figure 8 with data taken from Vogel, et al (91) and also reported by Hermansen (32). Dehn and Bruce (16) found a mean 0.94 $ml \cdot kg^{-1} \cdot mins^{-1}$ decline per year in a longitudinal study of aging. Thirdly, females have an aerobic capacity 30% less than males on an absolute basis ($\ell \cdot min^{-1}$), 25% less on a body weight basis and 12% on a lean body mass basis.

TABLE 8 Measured maximal O_2 uptake of military populations

Reference	Procedure	Subjects	Subject Description	Maximal O_2 Uptake $l.min^{-1}$	Maximal O_2 Uptake $ml.kg^{-1}.min^{-1}$
48	Continuous treadmill walking	US Soldiers n = 112	Age 17-19	3.48	49.4
			20-24	3.40	45.8
			25-29	3.07	41.1
			30-34	2.90	40.4
			35-39	2.58	35.7
			40-44	2.63	35.5
			45-49	2.77	34.8
			50+	2.57	35.4
46	Interrupted cycle	Swedish conscripts n = 37	Before training	3.04	45.1
			2 months training	3.68	54.3
25	Continuous treadmill walking	US Airmen	Age 20-24		40.3
			25-29		36.8
			30-34		36.0
			35-39		33.8
			40-44		34.0
			45-49		33.5
			50-53		34.0
30	Continuous cycle	USAF Cadets n = 79	Age 18-20	3.53	47.9
67	Interrupted treadmill running	US Infantry n = 234	Age 17-20		53.3
			21-25		50.0
			26-30		46.5
			31-35		43.8

Table 8 Directly measured maximal O_2 uptake of military populations (continued)

Reference	Procedure	Subjects	Subject Description	Maximal O_2 Uptake $l \cdot min^{-1}$	Maximal O_2 Uptake $ml \cdot kg^{-1} \cdot min^{-1}$
15	Interrupted treadmill running	US Infantry n = 34	Age 18-29	3.92	53.6
84	Interrupted treadmill running	British parachutists n = 22	Age 21-48	4.11	58.5
20a	Continuous cycle	French soldiers M=70	Age 18-22	3.15	46.3

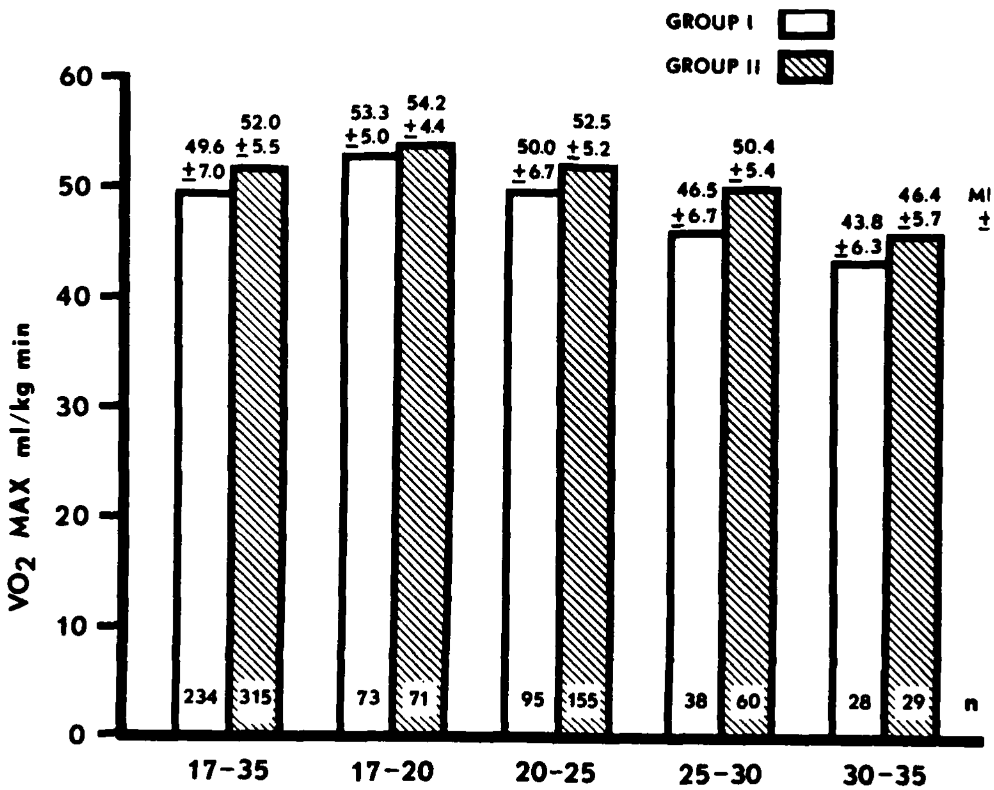


FIGURE 8. AGE DECLINE IN VO2max IN MODERATELY TRAINED (GROUP I) AND HIGHLY TRAINED (GROUP II) SOLDIERS (REF. 92)

Table 9 presents a selection of reported military population data on maximal oxygen uptake by predictive methods. Caution must be observed in comparing these values with the measured values presented in Table 8.

Aerobic Fitness Training

General

The response of aerobic capacity to physical training depends on such factors as: a) beginning level of fitness b) frequency of training, c) intensity of training, d) duration of training session and e) mode of training. Previously sedentary personnel who are at a low percentage of their potential maximal O_2 uptake will exhibit a greater response to a training program than previously active individuals who are close to their potential aerobic capacity. Female recruits typically show a greater improvement than males for this reason. Generally speaking, a 5-10% improvement in maximal O_2 uptake can be expected on the average during a 2 month training program. Improvements of 10% or greater usually take 3 months or more of intense training. Gains greater than 15% are not generally observed in the military setting.

Training frequency should be 3-5 times per week. Less than three times results in some loss between sessions while more than five times may precipitate an excessive injury rate. The intensity of training depends upon whether an improvement is desired or whether a level is to be maintained. Intensities represented by 60-80% of maximal heart rate are typically used. Duration, again, depends on the training objective but typically ranges from 20-60 minutes, the former generally considered a minimum as a training stimulus. The mode or type of training is selected to utilize large muscle masses in a rhythmic fashion so that cardiac output and oxygen transport are taxed. Running, backpacking, swimming and cycling are examples of aerobic

TABLE 9 Predictive values of maximal O_2 uptake of military populations

Reference	Procedure	Subjects	Subject Description	Maximal O_2 Uptake $\ell \cdot min^{-1}$	Maximal O_2 Uptake $ml \cdot kg^{-1} \cdot min^{-1}$
90	Astrand-Ryhming cycle	British Army recruits n = 438	Age 17-19		43.4
			19-21		40.9
			21-23		38.5
			23-25		39.9
			25-30		37.2
61	Astrand-Ryhming cycle	Canadian Forces personnel	Male		
			pre-recruit		46.7
			post-recruit		53.2
			Age 17-24		45.1
			25-29		38.8
			30-39		36.3
			40-55		32.4
			Female		
			pre-recruit		36.6
			post-recruit		41.9
			Age 17-24		36.8
			25-29		34.1
2	Astrand-Ryhming cycle	British Army personnel n = 3,070	Total		44.2
			Infantry		46.1
			Paratroopers		47.8
			Gurkha		58.5
31	Astrand-Ryhming cycle	Norwegian conscripts n = 801	Pre-training	2.90	45.0
85	Astrand-Ryhming cycle	British Army personnel n = 212	Female Age 18-30	2.20	35.9
16a	Continuous cycle	Dutch Army recruits	Male 17-25 n = 3642		50.7
			Female 17-23 n = 537		44.3

training modes. Weightlifting resistance training and calisthenics are ineffective aerobic training procedures. The literature on aerobic training is very extensive and will not be reviewed here. Pollock (73) reviews the factors influencing the responses to aerobic training.

BODY COMPOSITION

Relation to Fitness

Although not a component of fitness as defined in this chapter, the absolute and relative amounts of body fat and lean body mass are importantly related to exercise capacity. An earlier paragraph pointed out that muscle mass is a primary determinant of strength and that there is a high correlation between lean body mass and lifting capacity.

The degree of body fatness appears to be negatively correlated with aerobic power when expressed on a body weight basis. Vogel (89) reported a correlation coefficient of -0.52 in a group of 309 soldiers who were not highly trained and Smith and Searing (80a) showed a similar relationship in a mixed group of sailors. This correlation tends to disappear in groups who are well trained and thus more homogeneously fit and lean. Body fat, particularly in excess of 15% of body weight in men, represents an added "dead weight" which must be supported by the active muscles during walking and running and therefore detracts from the level of aerobic capacity when it is expressed on the basis of maximum oxygen delivery per kilogram of body weight.

Body composition also serves an important role when contrasting various fitness components between males and females or groups of different stature. In such cases, differences in exercise capacity may be largely or partly accounted for simply by differences in body weight, body fat or muscle mass. In weight supported exercise on the cycle ergometer, absolute VO_2

values are more meaningful as contrasted to weight supported treadmill exercise where VO_2 per kg body weight is more suitable. In comparing strength of women and men, both absolute force development as well as force per kg of lean mass are employed depending on the use of the information.

In summary, $\dot{V}O_2max$ expressed in $\ell \cdot min^{-1}$ provides a measure of the total amount of aerobic power the body can produce. This will be positively influenced by the absolute quantity of muscle. For the same level of training and fat content, muscular individuals are likely to out perform less muscled persons when significant amounts of weight are carried. This is due to the proportionally smaller "dead weight" being being carried by the more muscular individual. The greater the load the more relevant is the use of $\dot{V}O_2max$ in $\ell \cdot min^{-1}$ as compared to minimal loads where $\dot{V}O_2max$ adjusted by body weight ($ml^{-1} \cdot kg^{-1} \cdot min^{-1}$) is recommonded.

$\dot{V}O_2max$ expressed per kg body weight provides a measure of a person's ability to carry his own weight, e.g. during unloaded running. This will be negatively influenced by a high body fat content, muscular and non-muscular personnel would be expected to perform similarly. $\dot{V}O_2max$ expressed per kg lean body mass provides a measure of aerobic fitness regardless of body mass, lean mass or gender. Military commanders should be aware of these differences and potential problems of using units inappropriate to the situation.

Measurement

Body composition can only be measured indirectly in the living body. Of indirect methods, hydrostatic weighing to determine body density is most commonly used as the standard. This technique is coming increasingly under criticism because of the limited data upon which specific gravity calculations are made and particularly how they may vary between ethnic groups. An alternative to body density is the estimation of several body compartments such as muscle mass by K^{40} counting, bone density by dual beam photometry and body water by isotopic labeling or alcohol dilution. Electrical impedance is currently being evaluated to estimate body water and, in turn, body composition.

Outside the laboratory, equations using simple measures have been empirically developed to predict either percent body fat on lean body mass. Most common are those using three or more skinfold thickness measurements (28). The Durnin-Womersley age and gender adjusted tables are currently widely used throughout the NATO Forces (20). These tables employ four skinfolds, the biceps, triceps, subscapular and suprailiac sites.

Berres, Ulmer and Lamberty (7a) have derived equations for the Durnin-Womersley tables:

Eq. 5. Male: $\%fat - (4.95/1.1739-0.06227.\log(B) - 0.000555.A)$
-4.5×100

Eq. 6. Female = $\%\ fat = (4.95/1.1572-0.0647.\log(B) - 0.00038.A)$
-4.5×100

Where A is the age in years and B is the sum of the four skinfold thicknesses in mm.

Despite improvements in the use of th caliper (47), the measurement of skinfolds by the caliper technique suffers from a significant disadvantage when applied to widespread field use, that is the large variation among measurers. In the U.S. this has led to the search for other suitable anthropometric indicators that can be more reliably measured and yet are predictive of body fat. Hodgdon, et al (36,37) has reported good results with height plus circumference measurements in both males and females:

Eq. 7. Male: Body density = $-[.19077 \times \log_{10}(\text{Abdomen circumf.} - \text{neck circumf.})] + [.15456 \times \log_{10}(\text{height})] + 1.0324$

Eq. 8. Female: Body density = $-[.35004 \times \log_{10}(\text{abdomen} + \text{hip} - \text{neck circumf.})] + [.22100 \times \log_{10}(\text{height})] + 1.29579$

Density is converted to percent body fat according to the Siri equation: % BF = (4.95/density - 4.5) x 100. These equations are newly developed and some caution should be observed until further experience has been gained from their use.

Body Composition Values in Military Populations

Table 10 summarizes currently available data on percent body fat in military populations. Recently completed Army population studies in the U.K. and U.S. will significantly add to this data base in the future.

TABLE 10 Percent body fat values of military populations

Reference	Subjects	Method	% Body Fat Males	% Body Fat Females
65	US Army recruits - pre	Ref. 20	16.3	28.2
	- post		14.5	26.2
41	US Army recruits - pre	Ref. 20		
	Age 17-20		15.3	27.7
	20-25		16.1	28.8
	25-30		18.1	28.3
	30-35		22.4	31.0
68	US Army Infantry	Ref. 20		
	Age 40-41		25.0	
	42-43		26.6	
	44-45		26.9	
	46-47		26.2	
	48-49		23.8	
	50-51		26.5	
61	British Army recruits - pre	Ref. 28	14.2	
	- post		12.9	
28	British soldiers, n - 55	Hydrostatic weighing	12.5	
91	US Infantry age 17-20	Ref. 20	15.8	
	21-25		17.9	
	26-30		19.3	
	31-35		20.0	
9	Dutch Army professional entrees	Ref. 20	15.2	26.5
22	US Officer cadets	Body volume displace	14.5	23.6
2	British soldiers, n = 3,070	Ref. 28	17.6	
36, 37	US Naval personnel, age 18-56	Hydrostatic weighing	21.6	27.0

REFERENCES

1. Albrecht, K.-L. The W_{170}, an evaluation of measuring methods for fitness on Naval personnel. Proceedings of the First Meeting of NATO RSG-4, Toronto, 1978, DS/DR(78)98.

2. Amor, A.F. A survey of physical fitness in the British Army. Proceedings of the First NATO RSG-4 Meeting, Toronto, 1978, DS/DR(78)98.

3. Amor, A.F., D.E. Worsley and J.A. Vogel. Heart rate response to a single submaximal workload (Astrand's Test) as an estimate of maximal oxygen uptake in British Servicemen. Army Personnel Research Establishment Report No. 25/77, 1978, Farnborough.

4. Astrand, P.-O. and I. Rhyming. A nomogram for calculation of aerobic capacity (physical fitness) from pulse rate during submaximal work. J. Appl. Physiol. 7:218-221, 1954.

5. Atha, John. Strengthening muscle. In: Exercise and Sport Sciences Reviews, Vol. 9, 1981. Franklin Institute Press.

5a. Barnes, W.S. The relationship between maximum isometric strength and intramuscular circulatory acclusion. Ergonomics 23:351-357, 1980.

6. Bar-Or, O., R. Dotan and O. Inbar. A 30s all-out ergometric test - its reliability and validity for anaerobic capacity. Israeli J. Medical Sci. 13:326-327, 1977.

7. Bar-Or, O., R. Dotan, O. Inbar, A. Rothsteen, J. Karlsson and P. Tesch. Anaerobic capacity and muscle fiber type distribution in man. Int. J. Sports Medicine 1:82-85, 1980.

7a. Berres, F., H.-V. Ulmer and M. Lambertz. Calculation of total body fat from skinfold thickness using an age corrected formula. Eur J. Physiol. 384: Suppl. R35, 1980.

8. Bertina, F.M., H.A. Hendricks and M.J. Van Dijk. Evaluation of strength measurements of knee extension. Proceedings of the Fourth Meeting of NATO RSG-4, Natick, 1982, DA/A/DR(82)73.

9. Bertina, F.M. and M.J. van Dijk. Body composition and fitness of Dutch military personnel. Proceedings of the NATO RSG-8 meeting, 1983, Zeist.

10. Bertina, F.M., M.J. Van Dijk and E.R. Hendricks. First results of a new entry testing system of the Royal Netherlands Army. Proceedings of the Fifth Meeting of NATO RSG-4, Brussels, 1983, DS/A/DR(83)320.

11. Bosco, C., P.V. Komi, J. Tihanyi, G. Fekete and P. Apor. Mechanical power test and fiber composition of human leg extensor muscles. Eur. J. Appl. Physiol. 51:129-135, 1983.

12. Brue, F. and B. Melin. The direct determination of maximal aerobic and anaerobic power using a new mechanical cycle ergometer. Proceedings of the Fifth Meeting of NATO RSG-4, Brussels, 1983, DS/A/DR(83)320.

12a. Brue, F., B. Melin, J.P. Lamande. Determination de l'aptitude differentielle aerobie-anaerobie sur un nouveau type de cyclo-ergometre. Cinesiologie 24 (no. 103): 41-45, 1985.

13. Brue, F., C. DuFour, M. Filliaum, G. Duchaussoy, B. Melin. Le test vitesse maximale aerobie derriere cycliste. Conclusions d'une etude de faisabilite en unites en vue du reinplacement du test de Cooper. Rapport no. 85-06, C.E.R.B, BP610, F83800 Toulon-Naval, France, 1985.

13a. Carlson, B.R. Level of maximum isometric strength and relative load isometric endurance. Ergonomics 12:420-435, 1969.

14. Daniels, W.L. and J.A. Vogel. Comparison of aerobic power and dynamic lift capacity with performance during a five day sustained combat scenario. U.S. Army Rsch Instit. Env Medicine Technical Report (In press) 1984, Natick.

15. Daniels, W.L., D.M. Kowal, J.A. Vogel and R.M. Stauffer. Physiological effects of a military training program on male and female cadets. Aviat. Space Env.Med.50:562-566, 1979.

16. Dehn, M.M. and R.A. Bruce. Longitudinal variations in maximal oxygen intake with age and activity. J. Appl. Physiol. 33:805-807, 1972.

16a. Dijk, M.J. van, E.R. Hendriks, F.M. Bertina. Assessment of physical capabilities of Dutch military recruits. Sport Medical Center Report No. VFO 8508-1006, Utrecht, The Netherlands.

17. DuBois, P., D. Penson and J.P. Delwiche. Applicability of the NATO I bicycle Ergometer test. Proceedings of the Fifth Meeting of NATO RSG-4, Brussels, 1983, DS/A/DR(83)320.

18. Duggan, A. and D.J. Smith. Development of a regression model for the prediction of maximum aerobic power. Proceedings of the Fifth Meeting of NATO RSG-4, Brussels, 1983, DA/A/DR(83)320.

19. Duggan, A. and D.J. Smith. Assessment of physical fitness tests. Proceedings of the Fourth Meeting of NATO RSG-4, Natick, 1982, DS/A/DR(82)73.

20. Durnin, J.V.G.A. and J. Womersley. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Brit. J. Nutr 32:77-97, 1974.

20a. Eclache, J.P., S. Quard, J. Beaury and R. Flandrois. L'Aptitude physique des jeunes Francias de 20 ans. Proceedings First Meeting of NATO RSG-4, Toronto, 1978, DS/DR(78)98.

21. Exercise tests in relation to cardiovascular function. World Health Organ. Technical Report Series No. 388, 1968, Geneva.

22. Fielts, R.D., M.S. Morris, H.L. Johnson, R.E. Morris and H.E. Sauberlich. Body composition and work performance of cadets at the U.S. Military

Academy, West Point, N.Y. Letterman Army Instit. of Rsch Report No. 125, 1982, San Francisco.

23. Fox, E.L. A simple, accurate technique for predicting maximal aerobic power. J. Appl. Physiol. 35:914-916, 1973.

24. Frederick, F.A., R.C. Langevin, J. Miletti, M. Sacco, M.M. Murphy and J.F. Patton. Development and assessment of the Monark cycle ergometer for anaerobic muscular exercise. U.S. Army Rsch Instit. of Env. Medicine Technical Report No. T6/83, 1983, Natick.

25. Froelicher, V.F., Jr., M. Allen and M.C. Lancaster. Maximal treadmill testing of normal USAF aircrewmen. Aerospace Med. 45:310-315, 1974.

26. Froelicker, V.F., H. Brommell, G. David, I. Noguera, A. Stewart and M. Lancaster. A comparison of the reproducibility and physiologic response to three maximal treadmill exercise protocols, Chest 65:512-517, 1974.

27. Gollnick, P.D. and L. Hermansen. Biomechanical adaptation to exercise: anaerobic metabolism. In: Exercise and Sport Sciences Reviews, Vol. 1, 1973, Academic Press.

28. Haisman, M.F. The assessment of body fat content in young men from measurements of body density and skinfold thickness. Human Biology 42:679-688, 1970.

29. Haisman, M.F. Assessment of the exercise capacity of young men. Ergonomics 14:449-456, 1971.

30. Harger, B.S. and R.P. Ellis. Circulo - respiratory fitness in United States Air Force Academy Cadets. Aviat. Space Env. Med. 46:1144-1146, 1975.

31. Hermansen, L. Assessment of physical performance capacity in human subjects. Proceedings of the First Meeting of NATO RSG-4, Toronto, 1978, DS/DR(78)98.

32. Hermansen, L. Individual differences (Chapter 21). In: Fitness Health and Work Capacity - International Standards for Assessment, L.A. Larson, editor, MacMillan, New York, 1974.

33. Hermansen, L. and B. Saltin. Oxygen uptake during maximal treadmill and bicycle exercise. J. Appl. Physiol. 26:31-37, 1969.

34. Hermansen, L. and K. Karlsen. Maksimalt ok sygenopptak hos unge Norske menn. Tidsskrift for den Norske Laegeforening 13:929-937, 1972.

35. Hodgdon, J.A. and M.A. Beckett. Another validation of the RSG-4 maximal work capacity test. Proceedings of the Fifth Meeting of NATO RSG-4, Brussels, 1983, DA/A/DR(83)320.

36. Hodgdon, J.A. and M.A. Beckett. Prediction of percent body fat for U.S. Navy women from body circumferences and height. U.S. Naval Health Research Center Report No. 84-29, 1984, San Diego.

37. Hodgdon, J.A. and M.A. Beckett. Prediction of percent body fat for U.S. Navy men from body circumferences and height. U.S. Naval Health Research Center Report No. 84-11, 1984, San Diego.

38. Holloszy, J.O. Biochemical adaptations to exercise: aerobic metabolism. In: Exercise and Sports Sciences Reviews Vol. I, 1973, J.H. Wilmore editor, Academic Press, New York.

39. Kaijser, L. Limiting factors for aerobic muscle performance. Acta Physiologica Scandinavica. Supplementum 346, 1970.

40. Karlsson, J. and I. Jacobs. Onset of blood lactate accumulation during muscular exercise as a threshold concept. 1. Theoretical considerations. Int. J. Sports Med. 3:190-201, 1982.

41. Knapik, J.J., R.L. Burse anc J.A. Vogel. Height, weight, percent body fat, and indices of adiposity for young men and women entering the U.S. Army. Aviat. Space. Envir. Med 54:223-231, 1983.

42. Knapik, J., D. Kowal, P. Riley, J. Wright and M. Sacco. Development and description of a device for static strength measurement in the Armed Forces Examination and Entrance Station. U.S. Army Rsch Inst. Env. Med. Technical Report T2/79, 1979.

43. Knapik, J.J. and J.A. Vogel. Unpublished data from 9th U.S. Infantry Division, July 1983.

44. Knapik, J.J., J.A. Vogel and J.E. Wright. Measurement of isometric strength in an upright pull at 38 cm. U.S. Army Rsch Inst. Env. Med Technical Report T3/81, 1981, Natick.

45. Knapik, J.J., J.E. Wright, D.M. Kowal and J.A. Vogel. The influence of U.S. Army basic initial entry training on the muscular strength of men and women. Aviat. Space Envr. Medicine 51:1086-1090, 1980.

46. Knuttgen, H.G., L.-O. Nordesjo, B. Ollander and B. Saltin. Physical conditioning through interval training with young male adults. Med. Sci. Sports 5:220-226, 1973.

47. Kramer, H-J. and H.-V. Ulmer. Two second standardization of the Harpenden-caliper. Europ. J. Appl. Physiol. 46:103-104, 1981.

48. Kryzwicki, H.J., C.F. Consolozio and H.L. Johnson. Alterations in exercise and body composition with age. Proceedings of the Eighth Internat. Congress on Nutrition, Prague, 1969 (Excerpts Medica International Congress Series No. 213).

49. Larsson, L., G. Grumby and J. Karlsson. Muscle strength and speed of movement in relation to age and muscle morphology. J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 46:451-456, 1979.

50. Laubach, L.L. Comparative muscular strength of men and women: a review of the literature. Aviat.Space Environ. Med. 47:534-542, 1976.

51. Mader, A., H. Liessen, H. Heck, H. Philippi, R. Rost, P. Schurch and W. Hollmann. Zur Beurteilung der sportartspegifischen Ausdawerleistungsfahigkeit im Labor. Sportargt. Sportmed. 27:80-88, 1976.

52. Marcinik, E.J., J.A. Hodgdon, K. Mittleman and J.J. O'Brien. Aerobic/calisthenic and aerobic/circuit weight training program for Navy men: a comparative study. U.S. Naval Health Rsch Center Report No. 84-6, 1984, San Diego.

53. Marcinik, E.J., J.A. Hodgdon, J.J. O'Brien and K. Mittleman. Changes in fitness of Navy women following aerobic/calisthenics and aerobic/circuit weight training programs. U.S. Naval Health Rsch Center Report No.84-19, 1984, San Diego.

54. Margaria, R., P. Aghemo and E. Rovelli. Measurement of muscular power (anaerobic) in man. J. Appl. Physiol 21:1662-1664, 1966.

55. Maritz, J.S., J.F. Morrison, J. Peter, N.B. Strydom and C.H. Wyndham. A practical method of estimating an individual's maximal oxygen intake. Ergonomics 4:97-122, 1961.

56. McConville, J.T., E. Churchill, T. Churchill and R. White. Anthropometry of women of the U.S. Army - 1977 - Comparable data for the U.S. Army men. U.S. Army Natick Rsch and Devel. Command Technical Report TR-77/029, 1977.

57. McDaniel, J.W., R.J. Skandis and S.W. Madole. Weight lift capabilities of Air Force Basic Tra .ees. U.S. Air Force Aerospace Medical Research Laboratory Technical Report 83-0001, 1983.

58. Mitchell, J.H., J. Sproule and C.B. Chapman. The physiological meaning of maximal oxygen uptake test. J. Clin. Invest. 37:538-547, 1957.

59. Murphy, M.M., J.J. Knapik, J.A. Vogel and F .. Drews. Relationship of anaerobic power capacity to performance during a 5-day sustained combat scenario. U.S. Army Rsch. Instit. of Env. Medicine Technical Report T5/84, 1984, Natick.

60. Myers, D.C., D.L. Gebhardt, C.E. Crump and E.A. Fleishman. Validation of the military entrance physical strength capacity test. US Army Rsch. Instit. for the Behav. and Social Sciences, Technical Report 610, January 1984.

61. Myles, W.S. and C.L. Allen. A survey of aerobic fitness levels in a Canadian military population. Aviat. Space Env. Med. 50:813-815, 1979.

62. Myles, W.S. and R.J. Toft. A cycle ergometer test of maximal aerobic power. Europ. J. Appl. 49:121-129, 1982.

63. Nordesjo, L.-O. and R. Schele. Validity of an ergometer cycle test and measures of isometric muscle strength when predicting some aspects of military performance. Forsvarsmedicin 10:11-23, 1974.

64. Ouellette, R.G., E.J. Celentine, I. Noy, G.A.H. MacDonald and B. Rodden. Relationship between anthropometric and strength measurements of Canadian Forces Personnel. Defence Civil Instit. of Envr. Medicine Report No. 82-R-18, 1981, Toronto.

65. Patton, J.F., W.L. Daniels and J.A. Vogel. Aerobic power and body fat of men and women during Army basic training. Aviat. Space Env. Med 51:492-496, 1980.

66. Patton, J.F. and A. Duggan. The evaluation of tests of anaerobic power. Army Personnel Research Establishment Memorandum (In press).

67. Patton, J.F. and J.A. Vogel. An evaluation of physical fitness in the "Pro-Life" program, 2d Infantry Division, Korea. Proceedings of the U.S. Army Science Conference, June 1976, Vol. III, West Point, NY.

68. Patton, J.F., J.A. Vogel, J. Bedynek, D. Alexander and R. Albright. Response of 40 and over aged military personnel to an unsupervised, self-administered aerobic training program. Aviat. Space Env. Med. 54:138-143, 1983.

69. Patton, J.F., J.A. Vogel and R.P. Mello. Evaluation of a maximal predictive cycle ergometer test of aerobic power. Europ. J. Appl. Physiol. 49:131-140, 1982.

70. Pederson, A. and J.E. Nielsen. Evaluation of the RSG-4 test in relation to tests measuring oxygen uptake and other test methods used to determine $\dot{V}O_2$max. Proceedings of the Fifth Meeting of NATO RSG-4, Brussels, 1983, DS/A/DR(83)320).

70a. Petrofsky, J.S. and A.R. Lind. Isometric strength, endurance and the blood pressure and heart rate responses during isometric exercise in healthy men and women, with special reference to age and body fat content. Pflugers Arch 360:49-61, 1975.

71. Pheasant, S.T. Sex differences in strength - some observations on their variability. Applied Ergonomics 14:205-211, 1983.

72. Pirnay, F. and J.M. Crielaard. Measure de la puissance anaerobic alactique. Medicine du Sport 53:13-16, 1979.

73. Pollack, M.L. The quantification of endurance training programs. In: Vol I Exercise and Sport Sciences Review, 1973, Academic Press, New York.

74. Ramos, M.U. and J. Knapik. Instrumentation and techniques for the measurement of muscular strength in the human body. U.S. Army Rsch. Inst. Env. Med. Technical Report T2/80, 1980, Natick.

75. Rieck, A. Status of examination on muscle strength devices, its military applications, and practical experiences in NATO. Proceedings of the Fourth Meeting of NATO RSG-4, Natick, 1982, DS/A/DR(82)73.

76. Robertson, D.W. Development of an occupational strength test battery. U.S. Navy Personnel Rsch and Devel. Center Technical Report 82-42, 1982.

77. Saltin, B. and P.D. Gollnick. Skeletal muscle adaptability: significance for metabolism and performance. In: Handbook of Physiology - Section 10 Skeletal Muscle. Am. Physiol Soc, 1983, Bethesda.

78. Sharp, D.S., J.E. Wright, J.A. Vogel, J.F. Patton, W.L. Daniels, J. Knapik and D.M. Kowal. Screening for physical capacity in the U.S. Army: an analysis of measures predictive of strength and stamina, U.S. Army Rsch Inst. Env. Med. Technical Report T8/80, 1980, Natick.

79. Shepard, R.J. The prediction of "maximal" oxygen consumption using a new progressive step test. Ergonomics 10: 1-15, 1967.

80. Shepard, R.J., C. Allen, A.J.S. Benade, C.T.M. Davies, P.E. diPrompero, R. Hedman, J.E. Merriman, K. Myhre and R. Simmons. Standardization of submaximal exercise tests. Bulletin World Health Organ. 38:765-775, 1968.

80a. Smith, D.J. and C.S.M. Searing. INM test results - correlations with $\dot{V}O_2$max and 1.5 mile run times. Proceedings, Sixth Meeting of NATO RSG-4, Copenhagen, 1984.

81. Stamford, B.A. Step increment versus constant load tests for determination of maximal oxygen uptake. Europ. J. Appl. Physiol. 35:89-93, 1976.

82. Taylor, H.L., E. Buskirk and A. Henschel. Maximal oxygen uptake as an objective measure of cardiorespiratory performance. J. Appl. Physiol. 8:73-80, 1955.

83. Thorstensson, A. Muscle strength, fibre types and enzyme activities in man. *Acta Physiologica Scandinavia. Supplementum* 443, 1976.

84. Toft, R.J. Maximal oxygen uptake and muscle strength of well trained men. Army Personnel Research Establishment Memorandum 81M501, January 1981, Farnborough, UK.

85. Toft, R.J. and J.G. Griffiths. A comparative evaluation of basic fitness tests for the Womens Royal Army Corps. Army Personnel Research Establishment Memorandum 83M503, Feb 1983, Farnborough, UK

85a. Toft, R.J. and W.S. Myles. A cycle ergometer test of aerobic fitness. Army Personnel Rsch. Estab. Memorandum 81M516, Farnborough, UK, 1981.

86. Ulmer, H.-V. Relationship between W170, W and $\dot{V}O_2$max tests for aerobic endurance. Proceedings of the Fifth Meeting of NATO RSG-4, Brussels, 1983. DA/A/DR(83)320.

87. Ulmer, H.-V., U. Kraemer and G. Winter. Methological aspects for measuring maximal force and static endurance. Proceedings of the Fifth Meeting of NATO RSG-4, Brussels, 1983, DS/A/DR(83)320.

88. Ulmer, H.-V. and R. Trumm. Extrapolation of measured W_{170} results to maximal performance - a method for improving the comparability of the test results. Proceedings of the Fourth Meeting of NATO RSG-4, Natick, 1982, DA/A/DR(82)73.

89. Vogel, J.A. Revision of the U.S. Army's weight control program. Proceedings of the Fourth NATO RSG-4 Meeting, 1982, Natick, DS/A/DR(82)73.

90. Vogel, J.A. and J.P. Crowdy. Aerobic fitness and body fat of young British males entering the Army. Eur. J. Appl. Physiol. 40:73-83, 1979.

91. Vogel, J.A. and J.F. Patton. Evaluation of fitness in the U.S. Army. Proceedings of the First Meeting of NATO RSG-4, Toronto, 1978, DS/DR(78)98.

92. Vogel, J.A., M.U. Ramos and J.F. Patton. Comparison of aerobic power and muscle strength between men and women entering the U.S. Army Med. Sci. Sports 9:58, 1977.

93. Wasserman, K., kB.J. Whipp and A. Davis. Respiratory physiology of exercise: metabolism, gas exchange and ventilatory control. Int. Rev. Physiol. Resp. Physiol. 111:149-211, 1981.

94. Withers, R.T., G.J. Davies and R.G. Crouch. A comparison of three W_{170} protocols. Europ. J. Appl. Physiol. 37:123-128, 1977.

95. Wolthuis, R.A., V.F. Froelicher, J. Fischer and J.H. Triebwasser. The response of healthy men to treadmill exercise. Circ. 55:153-157, 1977.

96. Wright, J.E. Unpublished data from U.S. Army recruits at Fort Jackson, S.C., 1978.

97. Wright, J.E. Strength development: a review and perspective. Proceedings of Fourth Meeting of NATO RSG-4, Natick, MA, 1982, DS/A/DR (82) 73.

98. Wright, J.E., J.A. Vogel, J.B. Sampson, J.J. Knapik, J.F. Patton and W.L. Daniels. Effects of travel across time zones (jet-lag) on exercise capacity and performance. Aviat. Space Envr. Medicine 54:132-137, 1983.

DISTRIBUTION LIST

2 Copies to:

Commander
US Army Medical Research and Development Command
SGRD-RMS
Fort Detrick
Frederick, MD 21701

12 Copies to:

Defense Technical Information Center
ATTN: DTIC-DDA
Alexandria, VA 22314

1 Copy to:

Commandant
Academy of Health Sciences, US Army
ATTN: AHS-COM
Fort Sam Houston, TX 78234

1 Copy to:

Dir of Biol & Med Sciences Division
Office of Naval Research
800 N. Quincy Street
Arlington, VA 22217

1 Copy to:

CO, Naval Medical R&D Command
National Naval Medical Center
Bethesda, MD 20014

1 Copy to:

HQ AFMSC/SGPA
Brooks AFB, TX 78235

1 Copy to:

Director of Defense Research and Engineering
ATTN: Assistant Director (Environment and Life Sciences)
Washington, DC 20301

1 Copy to:

Dean
School of Medicine Uniformed Services
University of Health Sciences
4301 Jones Bridge Road
Bethesda, MD 20014